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TRANSLATION

CERTAIN PROBLEMS OF CONTEMPORARY BIOLOGICAL TELEMETRY

By

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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

WRIGHT-PATTERSON AIR FORCE BASE

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CERTAIN PROBLEMS OF CONTEMPORARY BIOLOGICAL TELEMETRY

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(Moscow)

Our country is the home of biological telemetry - a special scientific direction, developing problems of collection, conversion storage, and transmission of information about biological objects located at a distance from the recording device. Transmission of physiological information by radio was first carried out by A. A. Yushchenko and L. A. Chernavkin in 1932.

In spite of formally great age, biotelemetry nonetheless may be with all truth called a new scientific direction. Only in the last 5-10 years, in connection with the rapid development of radioelectronics, the appearance of semiconductor instruments, methods of microminiaturization of equipment, and new radio materials has the creation of various types of equipment for remote recording of biological information become possible. While up to 1957 only about twenty works concerning this question were published, at present they already number several hundred articles and several monographs. The method of remote investigation began to be applied for study of

activity of single nervous cells, for investigations of functions of separate organs and systems of organs, and also for monitoring the state and behavior of the integral organism both in physiological laboratory conditions, and also in clinical conditions, in production, in the stadium, and in the natural habitat of animals. Biotelemetry gradually becomes an all-embracing method with extraordinarily wide prospects of application in the most diverse regions of medicine and biology.

Rapid development of biotelemetry is caused not only by technical progress, but also by definite evolution of biological and clinical physiological concepts. While recently the basic bulk of medical and biological investigations was devoted to study of living objects in a state of relative rest or recording of a consecutive series of pictures, originating as a result of some effects (for instance frequency of pulse before and after load), now the object of analysis increasingly more and more are changes originating directly in the actual process of effect on the organism of various factors (work, etc.). In particular, it is possible to indicate the development of the physiology of activity (Bernshteyn, 1962), situations of which are widely used in athletic medicine. The necessity of investigations into conditions of natural behavior of animals and the labor and occupational activity of people makes biotelemetry an important tool of scientific progress.

Contemporary biotelemetric systems permit solution of a very wide scope of methodological problems. Basically these are: 1) registration of indicators of vital activity of various biological objects at significant distances; 2) feasibility of carrying out of biological investigations without obligatory contact of recording

device with object of investigation; 3) carrying out of investigations in process of active activity; 4) obtaining of information from objects travelling in space at significant speed; 5) obtaining of information from objects located inside an organism in cases when their direct contact with recording device is impossible.

However, one should not consider the great possibilities of the biotelemetric method separately from practical difficulties in the way of their realization. Thus, biotelemetric systems are more complicated in the constructional and exploitational respect than contact instruments. Existence of a radio channel limits the volume of transmitted information, and also requires the application of special measures for prevention of possible distortions (Parin, Bayevskiy, Gazenko, 1962). The manner of solution of a number of purely engineering problems depends on the biological peculiarities of the object of investigation.

The appearance of a large number of biotelemetric systems intended for use in the most diverse regions of medicine and biology undoubtedly plays an important role in guaranteeing further scientific progress. But only introduction into practice of similar equipment can properly raise the contemporary level of daily work of physicians and biologists. For that, besides purely organizational measures which are connected with securing mass production of biotelemetric equipment and wide discussion of the problems telemetry it is necessary to resolve the question on standarization of methods of biotelemetry and recommendations based on their application. Any new method (and biotelemetry, considering its specific character, in particular) before it receives widespread application, should not only be tested in a definite way but also by all means standardized. Standardization

first of all should be based on correct scientific classification.

Attempts to construct a scientific classification of biotelemetri systems are contained in many works. One of the latest most complete classifications is offered by V. V. Rozenblat (1963) distinguishing five forms of biotelemetry: board [on-board], dynamic, relay, stationary, and method of endo-radio probes. This classification is based mainly on consideration only of the practically widely applied directions of biotelemetry using various principles. Thus, relay biotelemetry is a particular case of the dynamic type for specific conditions of space flight. Stationary biotelemetry includes methods of transmission of information both by wires and also by radio. The method of endo-radio probes combines technically and biologically heterogeneous devices implanted and traveling inside the digestive tract.

The constructed contemporary scientific classification of biotelemetric systems apparently cannot be based on application of any one criterion. For instance, by range of operation, which is very important for engineers, it is possible to distinguish 3 or 4 type of systems: close range (up to 1-2 m), medium range (1-20 m), long range (up to 1-3 km) and super range (tens and hundreds of kilometers). It would be incorrect in creation of classification to consider only technical or only biological peculiarities of biotelemetric systems. It is impossible to settle finally only on already tested and practically proven systems, since a classification already in a year can become obsolete, inasmuch as a number of just beginning new directions will possibly, occupy a conspicuous place. Among such directions can be designated, for instance, the research in application of biological sources of energy for feeding biotelemetric systems or

work on application in biotelemetry of elements of computer technology.

As is known, wire and telemetering systems differ. It is possible to expect that in the very near future biotelemetric systems will appear using light or acoustic energy or radioactive radiations as a carrier of information. We will consider only biotelemetric systems based on the application of a radio link for communication between the source of information and the recording instrument. It is possible to classify such systems depending upon location of transmitting device relative to the object of investigation, circuit and constructional resolutions, purpose, and area of application of the biotelemetric system. One of the important peculiarities of a biotelemetric system is the method of location of transmitting device relative to the object of investigation. Thus, a broad class of biotelemetric systems has received the designation of dynamic according to criterion of positioning the transmitter on the investigated subject, which allows recording of biological data in process of movement and activity of the object, i.e., dynamically.

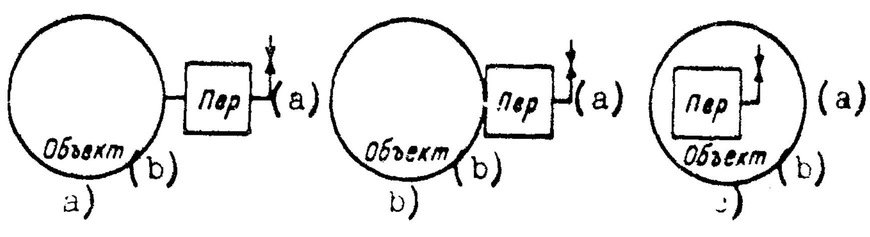

Fig. 1. Classification of biotelemetric systems depending upon the mutual location of object of investigation and transmitter. a) transmitter (пер) is located at certain distance from object; b) directly on object; c) transmitter is inside object.
KEY: (a) transmitter; (b) object.

There are three methods of locating transmitters: 1) at a certain distance from object of investigation; 2) on the object, and

3) inside it (Fig. 1).

If the transmitting device is outside the object of investigation (man), then the following variants of systems are possible: a) man, transmitter, and receiver are motionless relative to one another (use of telemetry for monitoring the condition of patients lying in a clinic); b) mutually motionless man and transmitter traveling relative to a receiver (pilot in aircraft).

With the movement of man and transmitter relative to the receiver, severe limitations are presented with respect to dimensions and weight of transmitter construction. This justifies singling out of such systems into a special group — dynamic.

Endo-radio probes include a number of biotelemetric systems with placement of transmitter inside the object of investigation for investigations of the digestive apparatus and are thus called implanted systems — devices placed for prolonged periods inside the body, subcutaneously or intracavitarily. At present implanted systems for dogs and apes are successfully developed.

Schematic and constructional resolutions of biotelemetric devices are connected with the technical capabilities of contemporary science. In establishment of criterion which could serve as the basis of classification schemes, the greatest attention will be allotted to long-range directions of further development of biotelemetry.

The question of power supplies of transmitting device has important significance in biotelemetry. It is especially serious for systems which are acclimatized in the organism. According to the principle of power supply of transmitters it is possible to distinguish four types of biotelemetric systems: autonomous feed, inductive feed,

external feed, and passive radiators with feed from biological sources of energy.

Autonomous feed is the most wide-spread in contemporary biotelemetry. For the great majority of investigations in sports, clinic, and physiology, periodic replacement of batteries or charging of storage batteries is fully permissible. Here the creation of circuits with economical energy requirement and small-size power supplies acquires special significance. However, for acclimatized systems it is impossible to ensure prolonged work by means of autonomous feed with the exception of separate cases of setting-up special experiments. It is true that there has been successfully created an acclimatized automatic heart stimulator with autonomous power supply calculated to work continuously for 3-5 years. However, for implanted systems, and also for systems where frequent replacement of power supplies is impossible, there has been developed the method of internal inductive feed. This method consists of an externally applied radio frequency generator radiating energy necessary for feed of transmitting device. In the transmitting device there is established a receiving circuit with rectifying elements which feeds the transmitting device. Such a system naturally has inevitable limitations with respect to the distances at which transmission is possible (Miller, 1961). Development has begun of so-called passive emitters, which for the first time were applied in radiosondes. Here the radiocapsule has a resonance circuit whose frequency depends on the reactive element, which varies, its parameters depending upon pressure, temperature, and so forth. Passive transmitters can be constructed on the principle of absorption or reverse transmissions of energy. In 1963 at the Fifth International Conference on Medical

Electronics a report (Flory, Natke, Zworykin, 1963) was represented about successful registration of electrocardiogram with the aid of passive transmitters.

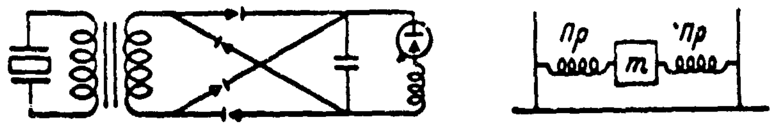

Fig. 2. System for conversion of motions of an animal into electrical energy for feed of a biotelemetric transmitter. On the left – electrical circuit, on the right – transducer of motions. Пр – spring; m – seismic mass.

Finally, a new promising direction is the use of biological energy. For these goals there can serve as a source of energy: muscular work; electrical, thermal, and chemical processes; processes of movement of the blood; and intestinal peristalsis. There recently appeared a report by a number of Soviet physiologists about the creation of a system of piezoelements implanted in muscular masses of a dog, providing energy sufficient to feed a telemetric transmitter. The device has a weight of 200 g and dimensions of 50 × 50 × 20 mm. In work by Long (Long, 1962) there are presented calculations of a transducer for conversion of movements of an animal into energy for feeding telemetric devices. Such a transducer consists of a seismic mass secured by two springs and connected with piezoelements (Fig. 2). The electronic circuit consists of a resonance transformer, rectifier, and generator on a tunnel diode. In 1963 an article appeared about the feed of an acclimatized heart stimulator from two piezoceramic elements secured onto the aorta (Myers and others, 1963). Also long known transmitting devices fed

from piezoelements are laryngophones which convert vibration of vocal chords into electrical energy.

The following criterion which determines structure and design features of biotelemetric system is the method of control of the transmitting device. In the majority of contemporary systems manual switching-on by experimenter is applied. For inductive systems manual switching on is carried out by starting the feeding radio frequency generator. In space flights, probably, for the first time it was necessary to contend with automatic and programmed switching on of biotelemetric equipment. Automatic control of the transmitter will be demanded in those cases when biologists conduct prolonged experiments or when the investigated object will be removed from experimenter. The radio frequency stimulator serves as example of automatic control, where the receiving device is excited by the generator in strict rhythm. Automatic control in the transmitting device itself may be connected, for instance, with commutation of several transducers on one channel (long-period time systems) or with periodically switched on transmitter.

The problem of biological control in telemetry is of great interest. Theoretically in the composition of transmitting or receiving devices the creation is possible of logical systems which ensure the output of controlling commands on a given algorithm (Fig. 3, I). Thus, for instance, a simple biotelemetric system being controlled by biopotentials of the heart could switch on by itself two counters, a time equalizing circuit and matrix of commands. Such a system will radiate signals only when the pulse rate becomes higher or lower than the given thresholds or when arrhythmic contractions appear. The computer of the transmitters can also switch-on the

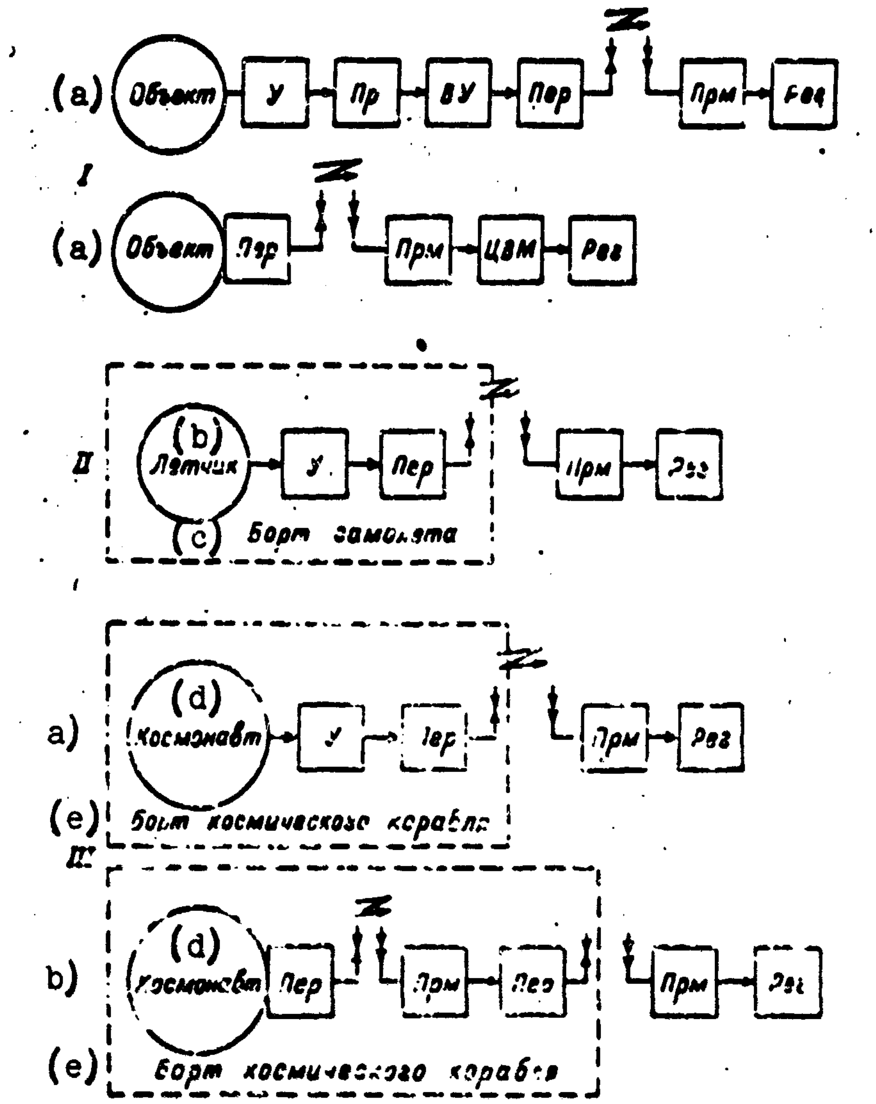

Fig. 3. Block-diagrams of biotelemetric systems. I — with computers in transmitter (above) and in receiver (below); II — diagram of aircraft biotelemetric system; III — diagram of contemporary a) and future b) cosmic biotelemetric system. У — amplifier; Пр — converter; ВУ — computer; ЦВМ — numerical computer; Пер — transmitter; ПРМ — receiver; Рег — recorder.
KEY: (a) object; (b) pilot; (c) aboard aircraft; (d) astronaut; (e) aboard spaceship.

transmitter with an increase in amplitude of muscular potentials above the given level set for registration of muscular activity or introduce signals into the systems of control. A possible variant is the switching on of the transmitter only after a drop in amplitude

of biopotentials below the given level set for limitation of electrocardiograph transmissions at heavy interferences caused by intense muscular activity. Telemetric systems with biocontrol, from all appearances, will have very great prospects in space medicine.

The possibilities of using computing elements in the composition of telemetric systems lead us to their classification by degree of conversion of primary information. Simple conversion of information is carried out in biotelemetric systems even without our participation when, as a result of sharp narrowing of band of frequencies of amplifiers, instead of the electrocardiogram transmission of pulses occurs characterizing the pulse rate. It is possible, however, to select special filters for selective singling out of interesting information, for instance α-rhythm of an electroencephalograph. Application of a logical device and especially a digital computer in the receiving device permits automatic appraisal of information in the process of its registration (Gazenko, Bayevskiy, 1961; Carbery and others, 1961; Goldberg, Wagoner, 1961). In Fig. 3 are shown block-diagrams of biotelemetric systems with computers in receiving and in transmitting sections.

Of the large number of technical criteria, we will consider only the question of construction of multichannel telemetric systems. It is clear that both for purposes of monitoring and also for research work it is insufficient to record only one parameter, and the majority of single-channel systems at present are used either in conditions of in-series transmission of several parameters, or in conditions of transmission on one channel of several parameters simultaneously, as is done in instruments of the type KRP-2 and 3

(Rozenblat, 1963). Multichannel biotelemetric systems can be designed with use of two principles; with packing of channels in transmitter and transmission of all parameters on one carrier frequency (AM-FM and FM-FM) and with transmission of every parameter on an independent radio channel.

Constructional and schematic resolutions of biotelemetric systems significantly depend on their purpose and area of application. Thus, transmitting and receiving devices for dynamic telemetry in conditions of the clinic, the gymnasium, or in the spaceship inevitably will have different characteristics. Therefore, in the classificational scheme the peculiarities of biotelemetric systems caused by their assignment also have to be reflected.

In aeromedicine the object of investigation is the activity of the pilot and the state of his physiological functions. The area of the cabin makes the location of transmitting equipment on body of pilot inexpedient, but the presence of powerful aircraft radio transmitters with corresponding sources of power supply completely resolves the problem of transmission of data at great distances (Glatt, Wiessinger, Pircher, 1953; Prutskoy, 1956; Samoylov, Peshkov, Myazdrikov, 1960; Barr, Voas, 1960). Therefore, the basic difficulties of aviation biotelemetry are connected with construction and distribution of electrodes and transducers on the pilot and with the provision of undistorted recording of data on the ground. Block-diagram of aircraft biotelemetric system is given in Fig. 3. II. First experiments on transmission of biological data from aircraft were conducted in 1952 in Switzerland (Smith, 1961).

Space biotelemetry was born in 1957 with the launch of the second artificial earth satellite with the dog Layka. (Chernov,

Yakovlev, 1958), although as long ago as the end of the 1940's in the United States experiments were conducted on transmission of biological information from vertically launched rockets (Henry et al., 1952). Astronautics exerted a great influence on development of biological telemetry. In space biotelemetry, in view of the serious limitations of weight, space, and power requirements of equipment installed on board the spaceship, besides questions of the arrangement of electrodes and transducers, micro-miniaturization of equipment has great value, increasing its economy and reliability of work over a prolonged period of time (Gazenko, Bayevskiy, 1961; Bayevskiy, 1962; Parin, Bayevskiy, Gazenko, 1962; Akulinichev, Bayevskiy, 1963). With increase of distance and duration of flights, naturally, one should expect a sharp decrease of capacity of telemetric channels. This will necessitate development of special measures undertaken for the fullest use of their carrying capacity (Bayevskiy, 1963). Furthermore, in prolonged flight releasing of the astronaut from constant wire communication with equipment aboard will be demanded. Internal cabin relay radio links will apparently become an integral part of systems of space biotelemetry (Gazenko, Bayevskiy, 1961; Bayevskiy, 1962; Yazdovskiy, Bayevskiy, 1962). In Fig. 3, III is represented a block-diagram of a contemporary (a) and possible future (b) space biotelemetric system.

Athletic biotelemetry at the present time is also experiencing a period of rapid development. It is necessary to note the great services of the Sverdlovsk biotelemetric group, which has created a number of original biotelemetric systems and used them in research in the physiology of sports (Rozenblat, 1962, 1963a).

The first physiological investigations of sportsmen in process of

training and competition in the world were conducted in Sverdlovsk (Rozenblat, 1962). Characteristic requirements for athletic bio-telemetrics are minimum weight and miniature dimensions of transmitting equipment placed on body of the athlete. Range of such systems varies from several meters to several kilometers; time of continuous operation — from several tens of minutes to several hours. Recently biotelemetry was applied not only for study of physiological functions of athletes, but also for recording behavior of athletes during competition [monitoring collisions of soccer players on field (Aagaara, Du Bois, 1962)] or for recording the character of execution of athletic exercises [for instance, telemetric recording of efforts and movements of oar for rowers (Sarychev, 1962)].

In the physiology of labor the application of biotelemetry is still in the initial stage. In industrial conditions for radio channels of biotelemetric systems there are present special requirements of noise-proofing and also absence of distortion during operations, connected with movement of the worker between machines, inside metallic cabins, etc. One of the first works in the area of industrial biotelemetry to be considered is the work of Parker with co-authors (Parker et al., 1953) connected with the recording of EKG and EEG for firemen. At present there are works on radio telemetric study of the activities of miners, metallurgical workers, railroad workers (Katsnel'son, Rosenblat, 1962; Vrychanu and co-authors, 1963; Solonin, 1963).

In clinical practice use of biotelemetry has only started. The serious diagnostic value of biotelemetric observations is attested to, for instance, by these facts. In the cardiological section of a Philadelphia hospital electrocardiographic recording was carried out

during movement (walking) for 147 patients with atherosclerosis. Here for 58% of the patients changes in the EKG were revealed only in movement. At the Fourth International Conference on Medical Electronics Zworykin and Hatke (Zworykin, Hatke, 1961) reported on a hospital telemetric system allowing observation of the patient from central point after surgical operations.

Other directions of clinical biotelemetry are investigation with the aid of endo-radio probes (Sorin, 1962; Mackay, 1963). This method constitutes an essential supplement to roentgenoscopy and roentgenography of the gastrointestinal tract and to investigation with the aid of stomach probes. Now there exist radio-pills for registration of pressure, temperature, acidity, and even for determination of localization of stomach hemorrhages (Kimoto and others, 1963). Only insufficient acquaintance of clinical physicians with biotelemetry prevents its wide introduction in diagnosis and medical examinations. It is possible to point out such possibilities of biotelemetry as monitoring of patients starting to rise from bed after a transferred infarction of myocardium, expert electroencephalographic investigations of neurological patients in conditions of natural behavior, and study of reactions of patients during medical procedures.

We now have great possibilities for expansion of biotelemetric investigations in the clinic. The radioelectrocardiograph TEK-1 is being mass produced by the All-Union Scientific Research Institute of Medical Instruments and Equipment (Timofeyev, Antselevich, 1960), soon production starts of Sverdlovsk instruments — radiopulsophones KRP-2M and REK-1. These instruments are incomparably more miniaturized than telemetric devices used for research purposes as recently as 10

years ago. In the very near future, in connection with advances of radioelectronic technology in the area of microminiaturization, it is possible to expect the appearance of microtelemetric systems whose dimensions and weight will be hundreds of times less than at present.

Further miniaturization of biotelemetric devices will have especially important significance for experimental physiology, which till now still makes insufficient use of them. Data are available on use of biotelemetry for investigations of higher nervous activity in animals [transmission of biopotentials of brain (Upson and others, 1962; Fischler, Frei, 1963)], heart activity [transmission of EKG (Ettlesson, Ping, 1962)]. Recently systems were produced for recording physiological functions with the aid of microtelemetric systems acclimatized in organism of animals — dogs, apes, cats. Thus, Ettleson and Ping (Ettlesson, Ping, 1962) published data on a three-channel system for recording EKG, breathing, and FKG (physiocardiograph) acclimatized in abdominal cavity of apes. There are data on radio transmitters with a weight of 15-30 g, acclimatized by birds and providing registration of their EKG and EEG during flight (Babskiy, Parin, 1964).

Biotelemetric investigations are of great interest in the area of physiology of agricultural animals, the pioneer of which in USSR is B. V. Panin (1958). He succeeded in studying a number of important physiological indices for caracul sheep on distances up to 5 km with free behavior of the animals in pasture conditions.

Thus, the purpose and area of application of biotelemetric systems put imprints on peculiarities of design, principles of construction and circuit resolutions.

Scientific classification based on calculation of all necessary

criteria must constantly determine the form of existing systems and their long-term lines of development. Thus, for purposes of ecological physiology at present systems can be used with location of transmitter on the investigated animal with autonomous feed, manual control, and without conversion of information. In perspective for these purposes biotelemetric systems of quite another kind can be created: with acclimitization inside the organism of the animal, with biological power supply, with biological control, and automatic processing of information in the receiving device.

Classification is not a dead scheme. It should be renovated and changed together with growth of technology and scientific progress. Appearance of new possibilities in the area of biotelemetry will lead to change of the classification scheme, just as the appearance of new problems in the area of application of this important method.

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